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(71) Applicant: **Rek, Pavel**
2383 Smartno pri Slovenj Gradcu (SI)

(72) Inventor: **Rek, Pavel**
2383 Smartno pri Slovenj Gradcu (SI)

(74) Representative: **Patentni Biro AF d.o.o.**
Kotnikova 32, p.p. 2706
1001 Ljubljana (SI)

(54) **A TOOL FOR INDUCTION HARDENING OF CYLINDERS WITH LOW FREQUENCY AND A METHOD OF INDUCTION HARDENING OF CYLINDERS WITH SAID TOOL**

(57) The present invention belongs to the field of metallurgy, more precisely to the field of devices for hardening. The invention relates to a tool for induction hardening of cylinders with low frequencies, comprising a cooling system designed to prevent deformation of the inductor material due to high inner forces caused by low frequencies of powering voltage. The tool (1) comprises a high-frequency inductor (4) and a low-frequency inductor (2) with a space arranged to receive the cylinder for hardening, wherein each inductor is provided with its own console (3, 5), a transformer for powering the inductors (2, 4) connectable to the consoles (3, 5), electronic circuit for controlling and electric circuit for powering the tool, as well as the cooling system. The latter comprises a cooling channel (23) on at least one coil of each inductor (2, 4) and/or a channel (31b, 32a, 33a) on each console (3, 5), a reservoir with cooling water connected to said cooling channels, a pump for allowing flow of the cooling fluid along the channels, a temperature sensor (28) for measuring cylinder temperature, and a sensor for measuring flow of cooling liquid. The cooling system further comprises a sprinkler (6) for cooling the cylinder, said sprinkler installed below the inductors (2, 4).

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Description

Field of the invention

[0001] The present invention belongs to the field of metallurgy, more precisely to the field of general methods and devices for heat processing of steel, for example annealing, heating, and hardening. In addition, the invention also belongs to the field of electrical engineering, more precisely to the field of devices for heating with electric, magnetic, or electromagnetic field. The invention relates to a tool for induction hardening of cylinders with low frequencies and to a method of induction hardening of cylinders with said tool.

Background of the invention and the technical problem

[0002] The use of induction hardening of steel dates back to the third decade of the twentieth century. A paper entitled »On inductive surface hardening« published in the newspaper Strojniški vestnik in 1957 reported on a special low frequency generator with high power and a high frequency generator with a reduced power and elongated operation.

[0003] During induction hardening of steel, the workpiece is heated in an induction loop and is cooled quickly after heating. This changes the crystal lattice of the material and consequently the hardness of the workpiece on the surface, while the core remains soft and tough.

[0004] In the case of cylinders with a smaller diameter, the hardened layer is thin in order to retain enough tough material and thus the load-bearing capacity. These cylinders are tempered with only one, namely a higher frequency, which varies between 200 and 1000 Hz. This is the so-called single-frequency induction hardening.

[0005] On the contrary, cylinders with larger diameters are required to have a larger thickness of the hardened layer, as this increases their life span. Consequently, these cylinders are heated with two inductors at different frequencies. This is a bi-frequency induction hardening, wherein the first inductor operates at a lower frequency and the second inductor at a higher frequency. The depth of the penetration of the heating energy is inversely proportional to the frequency of the electric current through the inductor loop, so the lowest possible frequency of the voltage is desired for thick cylinders. However, since lowering the frequency greatly reduces the lifetime of the induction loop or of the inductor and the inductor carrier, respectively, frequencies below 80 Hz are used only exceptionally, as the inductor sometimes could withstand only induction hardening of two cylinders. As a result, hardened rollers had a thinner layer of usable hardness (up to 20 mm) and thus a shorter lifespan.

[0006] Due to the mechanical stress on the material during low frequency treatments, damage to the inductor console or the inductor itself is common, which causes large additional production costs. In case of damage to the console and/or the inductor during the induction hardening process, the cylinder must be treated again, wherein the previously treated layer of the cylinder must be removed and the induction hardening process must be repeated with a new inductor or a new inductor console, or the cylinder has to be manufactured again from new material.

[0007] The technical problem addressed by the present invention is thus design of a tool for inductive hardening of cylinders, preferably with sizes from 250 to 1200 mm, which will elongate the life span of the inductor and the inductor console despite use of low voltage frequency used during induction hardening. The tool should enable a hardened (tempered) layer of thickness up to 60 mm of the cylinder depth, a higher quality of the structure of the tempered layer and use of lower frequencies of voltage of the inductor. It is a further aim of the invention to improve reliability and financial efficiency of the entire induction hardening process.

Prior art

[0008] Among the major manufacturers of induction machines are the company Inductotherm Europe Ltd as well as the Chinese company Inductotherm group China LTD. In Slovenia, the companies SALUS d.o.o., MaTeli d.o.o. and some smaller manufacturers produce machines for ironworks. Several solutions of tools for hardening iron cylinders and gears can be found in patent databases, but these mainly describe procedures and electrical circuits that enable the tools to work under certain conditions.

[0009] Utility model CN212486829 discloses an induction device for heating an open workpiece. The device comprises two induction coils adapted to the length of the workpiece. The induction coils have different winding directions. This solution is not similar to the present invention, which is based on two single coiled coils, which are powered with an electric voltage of different frequencies.

[0010] Utility model CN212486829 describes an integrated two-frequency induction heating equipment comprising a power cabinet body, a low-frequency and a medium-frequency power supply, a high-frequency and a medium-frequency inductor, a power supply machine, a discharge machine, and a detection device, wherein the power cabinet body is provided with a cooling section, a low-frequency power supply section, and a high-frequency section, all described components being described from the front to the back.

[0011] European patent EP2135485 relates to an inductor for the inductor hardening of metal, rod-shaped toothed racks, wherein the shell surface of the toothed rack is substantially plane in the region of the teeth, and wherein the remaining shell surface of the toothed rack is profiled in the cross-section. The invention proposes that both the toothed rack and the inductor be disposed in a stationary manner during the hardening process. For

this purpose the inductor is formed by a plurality of individual, substantially rod-shaped inductor elements, each extending parallel to the longitudinal axis of the toothed rack, wherein the teeth of at least one inductor element extend along the shell surface of the toothed rack, the inductor element hardening this predetermined surface region of the toothed rack, and wherein at least one inductor element extends along the remaining shell surface of the toothed rack, and hardens this predetermined surface region of the toothed rack. This solution does not solve the technical problem in the manner used by the present invention.

[0012] Utility model CN208685013 discloses a full automatization bolt induction hardening equipment. The equipment comprises a powering mechanism, a carousel mechanism, an induction heating mechanism, a quenching unloading mechanism, a transformer, and an electrical control cabinet. The unloading mechanism and the powering mechanism are installed on the flow one opposite another adjacent to the carousel mechanism, while the transformer is located on the right side of the induction heating mechanism, and the electrical control cabinet is located on the left side of the powering mechanism. The utility model uses cooling with water, wherein the water is supplied from a reservoir for water extending into a cooling channel of the single winding of the device, which ends with an inlet or an outlet. The present invention has cooling achieved in a different manner and significantly upgrades the known solutions.

Description of the solution to the technical problem

[0013] The present invention addresses the problem of short life spans of tools for induction hardening of cylinders, which in some cases lasts only few hours, and further solves disadvantages of known solutions. The technical problem is solved as defined in the independent claim, wherein preferred embodiments are defined in dependent claims.

[0014] The essence of the tool for induction hardening of cylinders according to the invention is in that the tool comprises a cooling system, so that large internal forces in the material caused by the low frequencies of the powering voltage do not deform the material of the inductor. The tool according to the invention thus comprises:

- at least one inductor with a space arranged to receive a cylinder for induction hardening and with at least one coil,
- at least one console for connection to a transformer, wherein the console also functions as a holder for the inductor,
- at least one sprinkler for cooling the cylinder, said sprinkler installed below the inductor,
- electronic circuit for controlling operation of the tool and electrical circuit for powering the tool, and
- a cooling system, comprising:
  - ◦ a cooling channel provided in the interior of at least one coil of the at least one inductor and on at least one console,
  - ◦ a reservoir arranged to store cooling water, said reservoir connected to the mentioned cooling channels and the sprinkler,
  - ◦ a pump for allowing flow of the cooling water through the cooling channels and the sprinkler,
  - ◦ at least one temperature sensor installed and arranged to measure the temperature of the cylinder,
  - ◦ at least one temperature sensor for measuring the temperature of the cooling water installed in at least one cooling channel of the inductor and in at least one cooling channel of the console or in at least one common line (pipe), into which the cooling water enters from the at least one cooling channel of the inductor and/or the console,
  - ◦ a flow sensor for measuring flow of the cooling water installed in at least one cooling channel of the inductor and in at least one cooling channel of the console or in at least one common line (pipe), into which the cooling water enters from the at least one cooling channel of the inductor and/or the console, and on the sprinkler or any line leading to the sprinkler.

[0015] In a preferred embodiment the tool comprises:

- a high-frequency inductor shaped as the letter omega and a pair of consoles of the high-frequency inductor for allowing connection to the transformer, wherein said consoles are installed each on its separate part (end) of the letter omega, wherein the circular part of the letter omega is arranged to receive the cylinder for induction hardening, wherein a suitable spacer is provided between said consoles for preventing sparking and possible short circuits,
- a low-frequency inductor shaped as the letter omega and a pair of consoles of the low-frequency inductor for allowing connection to the transformer, wherein said consoles are installed each on its separate part (end) of the letter omega, wherein the circular part of the letter omega is arranged to receive the cylinder for induction hardening, wherein a suitable spacer is provided between said consoles for preventing sparking and possible short circuits.

[0016] The inductor may have one coil (winding) or several coils, wherein one-coiled inductor is preferred.

[0017] Each of the inductors is shaped as the letter omega, i.e., has a circular part with a central open part arranged to receive the cylinder for induction hardening, and an attachment part (legs of the letter omega), which is configured for connection to the inductor console. Preferably, each inductor is made from mutually connected copper plates, so as to form a channel between them

along the entire height of the inductor or its coil, respectively. The plates are then curved into the shape of the previously mentioned letter omega. The cooling channel is thus provided in the interior of the circular part, so that the cooling liquid travels in the interior of the inductor, wherein the inlet and the outlet opening are provided on the attachment part. In the preferred embodiment, the inductor comprises at least one, preferably two temperature sensors for sensing the temperature of the cylinder, wherein said sensor is installed in a suitable place on the circular part facing towards the central part and consequently the cylinder to be hardened.

[0018] The inductor may be provided with reinforcements shaped as ribs provided on the transition part from the attachment part into the circular part, and/or the spacers, and/or the reinforcing-attachment ring installed on the exterior of the inductor, for allowing installation into a device for induction hardening of cylinders. These reinforcements and spacers enable longer lifespan of the tool, as spacers prevent inflating of the inductor due to the cooling water, while the reinforcements increase the rigidity of the system. In a preferred embodiment, the interior of the inductor at the entry into the cooling channel is provided with a router for directing the cooling water towards the circular part of the inductor and prevents a shorter route of the water avoiding the circular part. The router may be shaped as a plate, preferably as a slightly curved plate, which defines the required path of the water.

[0019] The console of each of the inductors is essentially a pair of consoles with the same shape, wherein the console has:

- a vertical part for connection to a transformer with connecting elements,
- a central part, and
- a part for connection to the inductor or its connection part, respectively.

[0020] All said parts of the console are provided with cut-out cooling channels for cooling water, wherein inlets and outlets of said cooling channels are connected to the reservoir for the cooling water.

[0021] The preferred shapes of the cooling channels are:

- the channel on the vertical part is shaped as the letter U turned upside down,
- the channel on the central part follows the shape of this part, wherein the central part is preferably shaped as a trapezium and the channel follows the trapezium shape and forms a loop or a turn,
- the channel on the part for connection to the inductor is shaped as the letter U.

[0022] The consoles are made from copper plates and the channels are made with milling. The channels of the console are covered with a cover adapted to the shape of the console, wherein the cover is attached by welding.

[0023] The sprinkler for cooling the cylinder is shaped as an open ring, comprising a cooling channel for the cooling water, said channel provided in the interior of the ring, at least one, preferably more connections for lines for cooling water from the reservoir enabling efficient sprinkling and cooling of the cylinder from all directions, said connections provided on the outer circumference. On the inner circumference of the sprinkler openings are provided, which are configured for allowing water to pass and sprinkle the cylinder for cooling. The openings may have different dimensions and may be provided at different angles, as long as they do not allow sprinkling of the inductors. Preferably the openings are provided at two angles, so that the cylinder is sprinkled at an angle and in the downwards direction. The sprinkler may be made from any suitable material, preferably from steel.

[0024] From the reservoir the water is brought via pipes or lines to the inlets of the cooling channels on the console (each console has three, i.e., a pair of consoles has six cooling channels), on the inductor and on the sprinkler. The cooling system preferably allows the following movement of the cooling liquid:

- along the whole circular part of the inductor,
- along the vertical part of the console upwards and then downwards,
- along the central part of the console in the shape of a loop or a turn,
- along the connection part for the inductor downwards and upwards, and
- sprinkling of the cooling water on the cylinder to be induction hardened with the tool according to the invention.

[0025] The precise path of the cooling water depends on the position of inlets and outlets.

[0026] The cooling system of the tool according to the invention enables cooling of the inductors and the consoles, which significantly improves the life span of the tool, as well as cooling of the treated cylinder, which improves its quality and contributes to the required structure of the tempered layer of the cylinder. The controller or the electronic circuit for controlling the tool allows monitoring and control of the cooling process, wherein the circuit is arranged to terminate hardening by terminating heating of inductors, in case of sensed:

- too high temperature of the water detected on any of the sensors, and/or
- irregular flow through flow sensors or absence of flow, and/or
- cooling not being performed.

[0027] The sensors follow the temperature of cooling water entering the channel as cool water and exits the cooling channel as heated water. The controller of the tool for induction hardening of cylinders via a computer program tracks the temperature sensed by the temper-

ature sensors at the exits (outlets) of the channels. In case the measured temperature is too high, the controller terminates the process of hardening. Usually, the threshold for the water temperature leaving the cooling channels is below 40 °C.

[0028] To allow measuring the workpiece temperature, temperature sensors are installed through measuring holes in the inductors, preferably on the stands besides the inductors, where two sensors-pyrometers are installed. The temperature sensor is also provided between inductors and between the inductor and the sprinkler. The flow sensor is any suitable flow sensor and is installed at several locations, preferably in the inductor in the outlets of cooling channels, at least in one channel outlet on consoles, on joined lines (pipes) into which cooling water from cooling channels runs, and in the sprinkler. In case any of the channels bursts or is deformed in any other manner, the required flow would not be sensed and the controller would terminate the process of induction hardening.

[0029] The induction frequency of the tool according to the invention is continuously adjustable, which allows different depths of the induction hardening, up to the useful depth of 60mm. The device has two inductors operating simultaneously, wherein one is with high frequency from 200Hz to 1000Hz and the other is with low frequency from 50Hz to 200Hz. This allows longer hardening times, larger supply of power and achieving deeper depths of hardening.

[0030] The tool according to the invention may be installed in any machine for induction hardening of cylinders, wherein different inductors may be attached to the said consoles based on the dimension of cylinders and frequencies for hardening. The inductors are through corresponding consoles connected to the transformer that powers the inductors with screws.

[0031] The present invention as described above, prevents the inner mechanical forces at low frequencies from causing mechanical deformation of the low-frequency inductor. The construction of the tool for induction hardening with low frequencies according to the invention the depth of the hardened layer is increased up to 60 mm for cylinders with diameter from 250 to 1200 mm, wherein the quality of the structure of the hardened layer is increased at lower frequencies of power voltage. The reinforcements and dimensioning of the console and the inductor allow prolonged life span of the tool and thus increased reliability of the whole system for hardening, which decreases the costs for the induction hardening tools per one unit of the final product.

[0032] A method of the induction hardening of cylinders using the tool according to the invention comprises the following steps:

a) placement of at least one inductor on at least one console and placement of the tool into the device for hardening cylinders, so that the reinforcement-connecting ring is connected to suitable holders,

b) connecting at least one said console to the transformer,

c) placement of the cylinder to be hardened, so that the cylinder can pass through the circular part or at least on inductor,

d) heating the cylinder through frequency induction, wherein the cylinder is moving downwards through said inductor, and

e) simultaneously with the heading in step d) cooling of the inductor, the console and the cylinder using the cooling system as described above, wherein the temperature of cooling water and the cylinder is monitored in order to terminate the hardening process in case of too high temperatures.

[0033] The tool for induction hardening of cylinders with low frequencies according to the invention will be described in further detail based on exemplary embodiment and figures, which show:

Figure 1 The tool according to a possible embodiment
Figure 2 The inductor with the console according to a possible embodiment
Figure 3a The inductor
Figure 3b Construction of the inductor in cross-section
Figure 3b A router for directing the cooling water inside the inductor
Figure 4a The console
Figure 4b The console from the bird's perspective
Figure 5 A possible embodiment of the sprinkler for sprinkling the cylinder

[0034] Figure 1 shows a possible embodiment of the tool 1 for induction hardening of cylinder, said tool comprising:

- a low frequency inductor 2 with a space arranged to receive a cylinder for induction hardening and with at least one coil,
- a high frequency inductor 4 with a space arranged to receive a cylinder for induction hardening and with at least one coil,
- two pairs of consoles 3, 5 for connection to a transformer, wherein one pair of consoles is for the high frequency inductor and the second pair of consoles is for the low frequency inductor,
- a sprinkler 6 for cooling the cylinder, said sprinkler installed below the inductors 2, 4,
- electronic circuit for controlling operation of the tool and electrical circuit for powering the tool, and
- a cooling system, comprising:
  - a cooling channel 23 provided in the interior of at least one coil of each inductor 2, 4 and channels 31b, 32a, 33a on each console 3, 5,
  - at least one sprinkler 6 for cooling the cylinder,

said sprinkler installed below the inductor 2, 4,
◦ a reservoir arranged to store cooling water, said reservoir connected to the mentioned cooling channels and the sprinkler 6,
◦ a pump for allowing flow of the cooling water through the cooling channels and the sprinkler (6),
◦ at least one temperature sensor installed and arranged to measure the temperature of the cylinder,
◦ at least one temperature sensor for measuring the temperature of the cooling water installed in at least one cooling channel 23 of the inductor 2, 4 and in at least one cooling channel of the console 3, 5 or in at least one common line, into which the cooling water enters from the at least one cooling channel of the inductor 2, 4 and/or the console 3, 5,
◦ a flow sensor for measuring flow of the cooling water installed in at least one cooling channel 23 of the inductor 2, 4 and in at least one cooling channel 31b, 32a, 33a of the console 3, 5 or in at least one common line, into which the cooling water enters from the at least one cooling channel of the inductor and/or the console.

[0035] The frequency of the power voltage for the low frequency inductor 2 is between 50 and 200 Hz. The frequency of the power voltage for the high frequency inductor 4 is between 200and 1000 Hz.

[0036] Figure 2 shows the shape of the inductor 2 in the shape of letter omega and a pair of consoles 3 of the low frequency inductor 2 for connection to the transformer, wherein said consoles 3 are installed each on its own end of the letter omega, i.e., the attachment part 22 of the inductor 2, and the circular part of the letter omega is arranged to receive the cylinder to be hardened, wherein between both consoles 3 a suitable spacer is provided for preventing sparking and possible short circuits. The shape of the inductor is the same for the high frequency inductor 4. The high frequency inductor may have the same height as the low frequency inductor or the high frequency inductor is shorter than the low frequency inductor. The inductor, regardless of the type - low or high frequency - has reinforcements 26 in the shape of ribs and/or spacers and/or a reinforcement-attachment ring 27 installed on the exterior of the inductor in order to allow installation into a device for hardening of cylinders.

[0037] Figure 3a shows a bird's perspective of the inductor 2, with a visible attachment part 22, the circular part 21 and the reinforcement 25 on the transition from the attachment part 22 into the circular part 21, which enables higher rigidity of the tool.

[0038] Each inductor 2, 4 is made from mutually connected copper plates, so as to form a channel 23 along the entire height of the inductor or its coil, respectively, as shown in figure 3b. The plates are then curved into the shape of the letter omega. The cooling channel 23 is thus provided in the interior of the circular part 21, so that the cooling liquid moves in the interior of the inductor 2, wherein the inlet (entry) hole 24 and the outlet (exit) hole 25 are on the attachment part 22. In a preferred embodiment the inductor 2 comprises two temperature sensors 28 for sensing the temperature of the cylinder, wherein said sensor is installed in a suitable place 21a on the circular part 21 facing towards the central part and consequently the cylinder to be hardened.

[0039] Figure 3c shows the construction at the entry into the cooling channel 23 of the inductor 2, where a router 29 is installed for guiding water towards the circular part 21 of the inductor 2 and prevents the shorter path of the water without entering into the part 21.

[0040] The console 3 each of the inductors 2, 4 is shown in figure 4a and comprises:

- a vertical part 31 for connection to a transformer with connecting elements 31a,
- a central part 32 and
- a part 33 for connection to the inductor or its attachment part, which is provided with suitable holes for connection.

[0041] All said parts of the console are provided with cut-out cooling channels 31b, 31c, 31d for cooling water, wherein inlets and outlets of said cooling channels are connected to the reservoir for the cooling water.

[0042] The preferred shapes of the cooling channels are:

- the channel 31b on the vertical part 31 is shaped as the letter U turned upside down,
- the channel 31c on the central part 32 follows the shape of this part, wherein the central part is preferably shaped as a trapezium and the channel follows the trapezium shape and forms a loop or a turn,
- the channel 33a on the part 33 for connection to the inductor is shaped as the letter U.

[0043] Each console is made from copper plates and the channels are made with milling. The channels of the console are covered with a cover adapted to the shape of the console, wherein the cover is attached by welding.

[0044] The cooling system thus enables the following movement of the cooling liquid:

- along the whole circular part 21 of the inductor 2, 4,
- along the vertical part 31 of the console 3 upwards and then downwards,
- along the central part 32 of the console 3 in the shape of a loop or a turn,
- along the connection part 33 for the inductor downwards and upwards, and
- sprinkling of the cooling water on the cylinder to be induction hardened with the tool 1.

[0045] Between the two consoles, which are connect-

ed to ends of the inductor shaped as the letter omega, a spacer or an insulating plate is provided, which thus forms a whole with a screw connection, wherein the screws are made from non-magnetic material.

[0046] The sprinkler 6 for cooling the cylinder shown in figure 5 is shaped as an open ring 61, which is in the interior provided with a channel for cooling liquid and on the outer circumference at least one, preferably more connections 62 for the lines (pipes) of the cooling water from the reservoir, in order to allow efficient sprinkling and cooling of the cylinder from all directions. The inner circumference of the sprinkler is provided with openings 63, through which the water sprinkles on the cylinder, thus cooling it. The openings 63 may have any dimensions and may be at different angles, as long as they do not allow sprinkling on the inductors 2, 4. Preferably, the openings 63 are provided at two angles, to allow sprinkling of the cylinder at an angle and in the downwards direction. The sprinkler 6 may be made from any suitable material, preferably from steel.

Claims

1. A tool (1) for induction hardening of cylinders with low frequencies, said tool comprising:

- at least one inductor (2, 4) with a space arranged to receive a cylinder for induction hardening and with at least one coil,
- at least one console (3, 5) for connection to a transformer, wherein the console also functions as a holder for the inductor (2, 4),
- electronic circuit for controlling operation of the tool and electrical circuit for powering the tool, and
- a cooling system, comprising:
  - ◦ a cooling channel (23) provided in the interior of at least one coil of the at least one inductor (2, 4) and on at least one console (3, 5),
  - ◦ at least one sprinkler (6) for cooling the cylinder, said sprinkler installed below the inductor (2, 4),
  - ◦ a reservoir arranged to store cooling water, said reservoir connected to the mentioned cooling channels and the sprinkler (6),
  - ◦ a pump for allowing flow of the cooling water through the cooling channels and the sprinkler (6),
  - ◦ at least one temperature sensor installed and arranged to measure the temperature of the cylinder,
  - ◦ at least one temperature sensor for measuring the temperature of the cooling water installed in at least one cooling channel (23) of the inductor (2, 4) and in at least one cooling channel of the console (3, 5) or in at least one common line, into which the cooling water enters from the at least one cooling channel of the inductor (2, 4) and/or the console (3, 5),
  - ◦ a flow sensor for measuring flow of the cooling water installed in at least one cooling channel (23) of the inductor 2, 4) and in at least one cooling channel of the console (3, 5) or in at least one common line, into which the cooling water enters from the at least one cooling channel of the inductor and/or the console, and on the sprinkler (6) or any line leading to the sprinkler.

2. The tool (1) for induction hardening of cylinders with low frequencies according to claim 1, wherein the tool (1) further comprises:

- a high-frequency inductor (4) with high frequency from 200Hz to 1000Hz shaped as the letter omega and a pair of consoles (5) of the high-frequency inductor (5) for allowing connection to the transformer, wherein said consoles (5) are installed each on its separate end of the letter omega, wherein the circular part of the letter omega is arranged to receive the cylinder for induction hardening, wherein a suitable spacer is provided between said consoles for preventing sparking and possible short circuits,
- a low-frequency inductor (2) with a low frequency from 50Hz to 200Hz shaped as the letter omega and a pair of consoles (3a, 3b) of the low-frequency inductor for allowing connection to the transformer, wherein said consoles (3a, 3b) are installed each on its separate end of the letter omega, wherein the circular part of the letter omega is arranged to receive the cylinder for induction hardening, wherein a suitable spacer is provided between said consoles for preventing sparking and possible short circuits.

3. The tool (1) for induction hardening of cylinders with low frequencies according to claim 1 or claim 2, wherein the inductor (2, 4) has one or more coils, preferably one coil.

4. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein each inductor is made from mutually connected copper plates, so as to form a channel between the plates, said channel running along the height of the inductor or its coil, respectively, and wherein the plates are curved into said omega-shape.

5. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding

claims, wherein the inductor (2, 4) comprises at least one, preferably two, temperature sensors (28) for sensing the temperature of the cylinder, wherein said sensor is installed in a suitable place on the circular part (21) facing towards the central part and thus the cylinder for induction hardening.

6. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein the inductor (2, 4) has reinforcements shaped as ribs (26) provided on

the transition part from the attachment part (22) into the circular part (21), and/or the spacers, and/or
the reinforcing-attachment ring (27) installed on the exterior of the inductor (2, 4), for allowing installation into a device for induction hardening of cylinders.

7. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein the interior of the inductor (2, 4) at the entry into the cooling channel is provided with a router (29) for directing the cooling water towards the circular part (21) of the inductor and prevents a shorter route of the water avoiding the circular part (21).

8. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein each console comprises:

- a vertical part (31) for connection to a transformer with connecting elements (31a),
- a central part (32), and
- a part (33) for connection to the inductor or its connection part, respectively,
- wherein all said parts of the console (3) are provided with cooling channels (31b, 32a, 33a) for cooling water, said channels covered with welded covers, wherein inlets and outlets (31c, 31d, 32b, 32c, 33b, 33c) of said cooling channels are connected to the reservoir for the cooling water.

9. The tool (1) for induction hardening of cylinders with low frequencies according to the preceding claim, wherein the channels are shaped in the following manner:

- the channel (31b) on the vertical part (31) is shaped as the letter U turned upside down,
- the channel (32a) on the central part (32) follows the shape of this part, wherein the central part is preferably shaped as a trapezium and the channel follows the trapezium shape and forms a loop or a turn,
- the channel (33a) on the part (33) for connection to the inductor is shaped as the letter U.

10. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein the sprinkler (6) for cooling the cylinder is shaped as an open ring (61), comprising:

- a cooling channel for the cooling water, said channel provided in the interior of the ring,
- at least one, preferably more connections (62) for lines for cooling water from the reservoir enabling efficient sprinkling and cooling of the cylinder from all directions, said connections (62) provided on the outer circumference,
- openings (63) provided on the inner circumference of the sprinkler, wherein said openings are configured for allowing water to pass and sprinkle the cylinder for cooling.

11. The tool (1) for induction hardening of cylinders with low frequencies according to the preceding claim, wherein the openings (63) have different dimensions and are provided at two angles to allow sprinkling of the cylinder at an angle and in the downwards direction.

12. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein the cooling system enables the following movement of the cooling fluid:

- along the whole circular part (21) of the inductor (2, 4),
- along the vertical part (31) of the console (3) upwards and then downwards,
- along the central part (32) of the console (3) in the shape of a loop or a turn,
- along the connection part (33) for the inductor downwards and upwards, and
- sprinkling of the cooling water on the cylinder to be induction hardened with the tool (1).

13. The tool (1) for induction hardening of cylinders with low frequencies according to any of the preceding claims, wherein the electronic circuit for controlling the tool (1) is configured to monitor and control the cooling process, wherein the circuit is arranged to terminate induction heating by terminating heating of the inductors (2, 4), in case of sensed:

- too high water temperature on any of the sensors, and/or
- irregular flow through flow sensors or absence of flow, and/or
- cooling not being performed.

14. A device for induction hardening of cylinders, com-

prising the tool (1) according to any of the preceding claims.

15. A method for induction hardening of cylinders using the tool (1) or the device according to any of the preceding claims, wherein the method comprises the following steps:

f) placement of at least one inductor (2, 4) on at least one console (3, 5) and placement of the tool (1) into a device for hardening cylinders, so that the reinforcement-connecting ring (27) is connected to suitable holders,
g) connecting at least one said console (3, 5) to a transformer,
h) placement of the cylinder to be hardened, so that the cylinder can pass through the circular part (21) or at least on inductor (2, 4),
i) heating the cylinder through frequency induction, wherein the cylinder is moving downwards through said inductor (2, 4), and
j) simultaneously with the heading in step d) cooling of the inductor (2, 4), the console (3, 5) and the cylinder using the cooling system, wherein the temperature of cooling water and the cylinder is monitored in order to terminate the hardening process in case of too high temperatures.

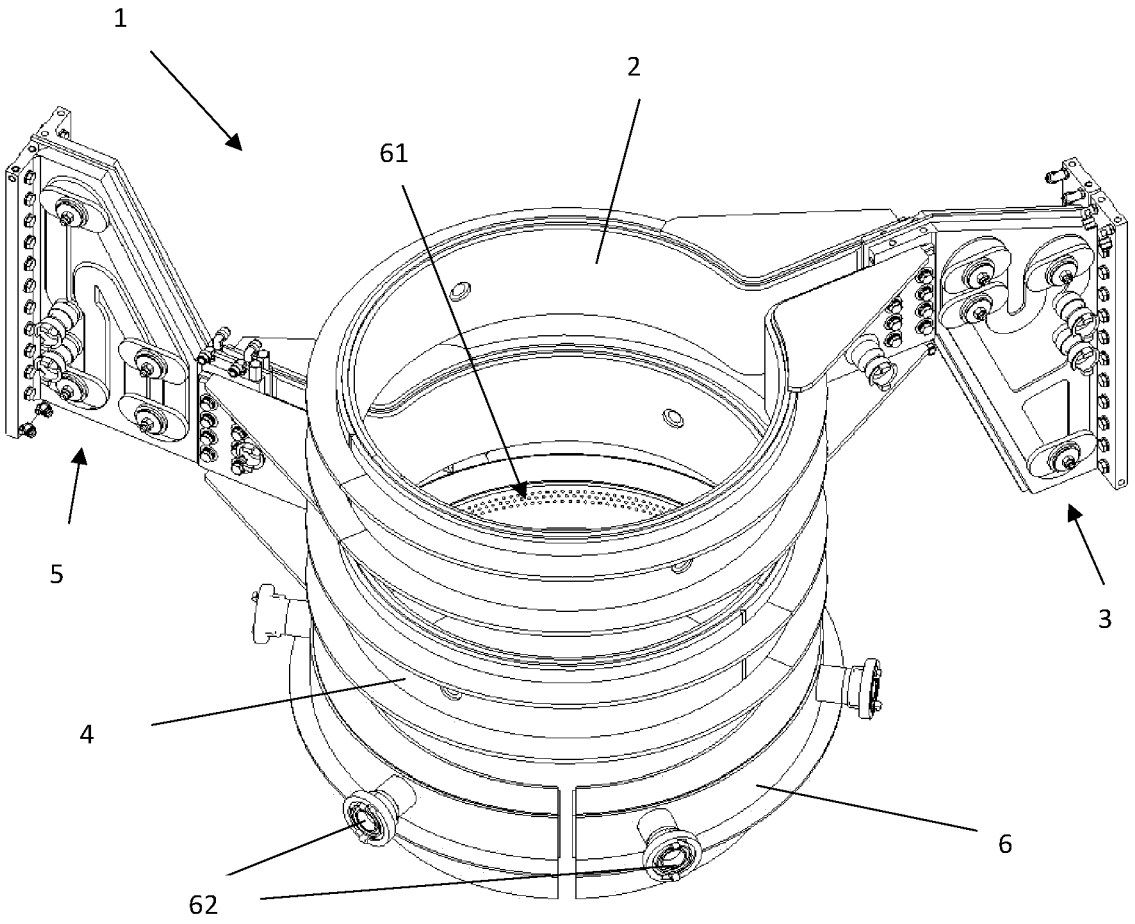

Figure 1

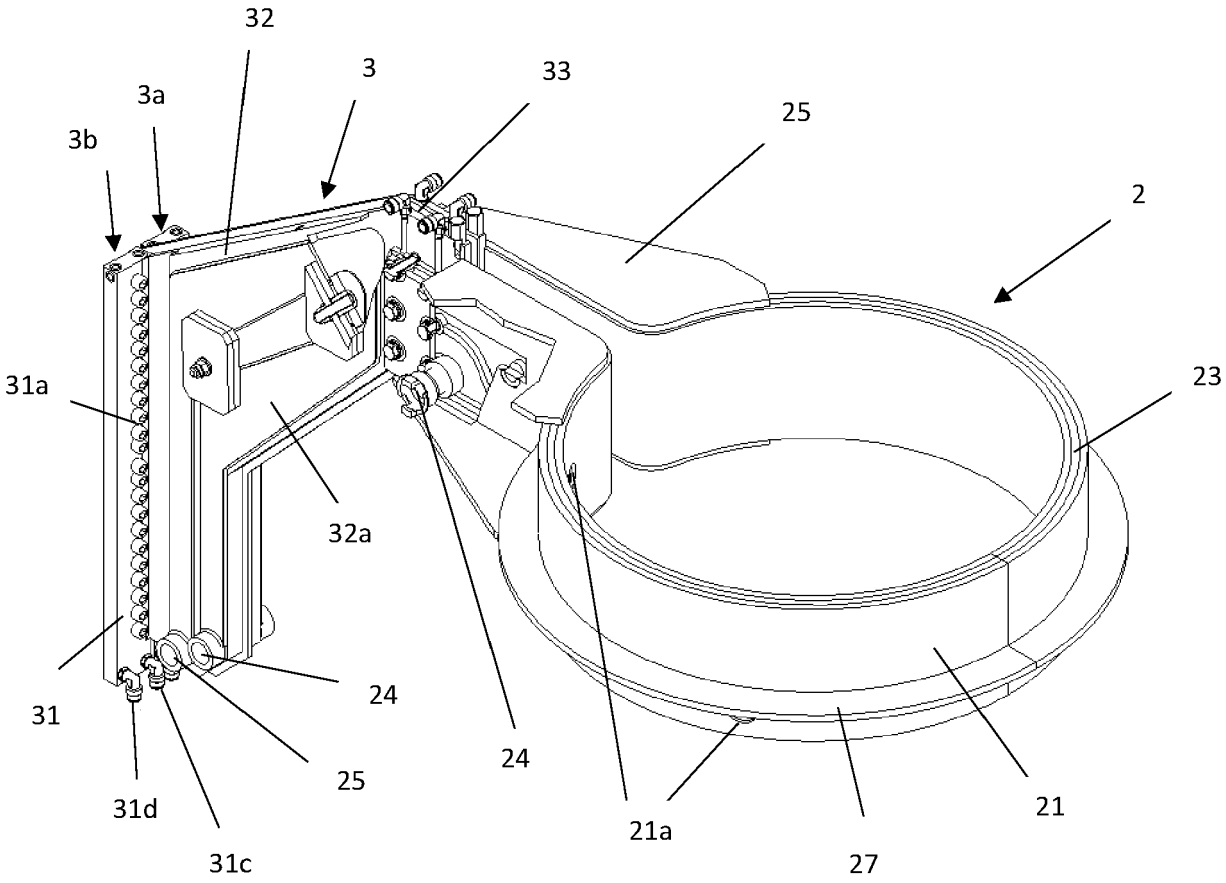

Figure 2

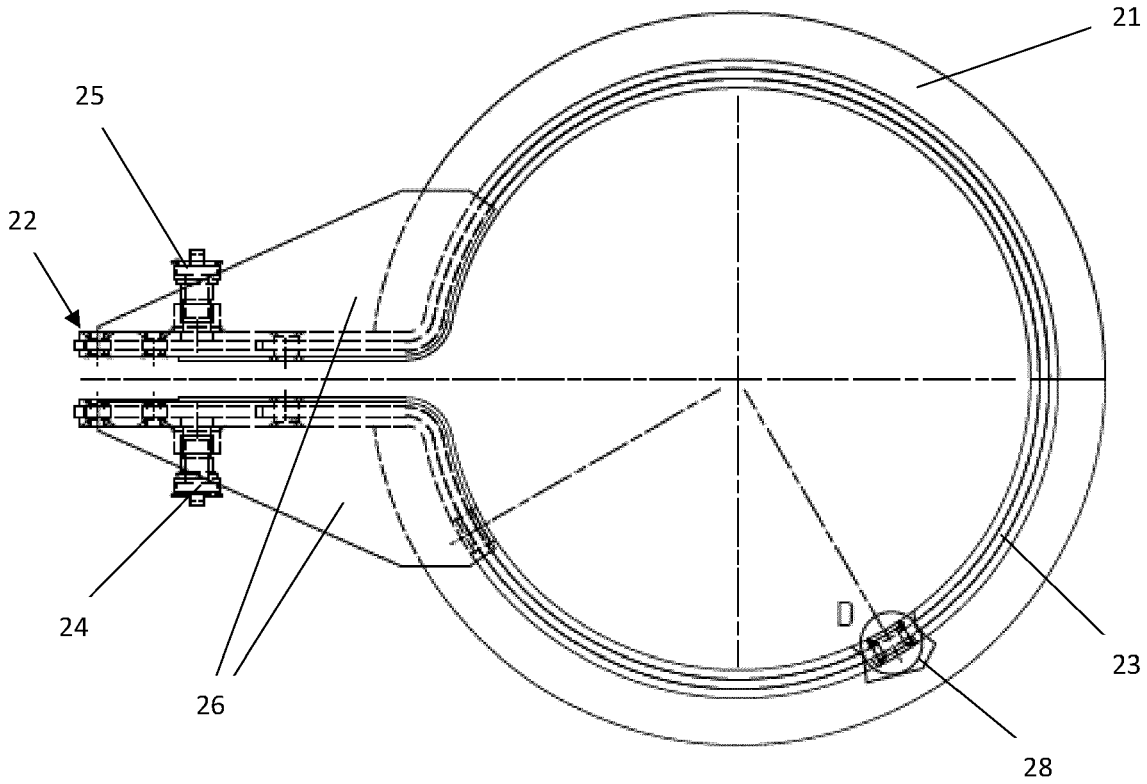

Figure 3a

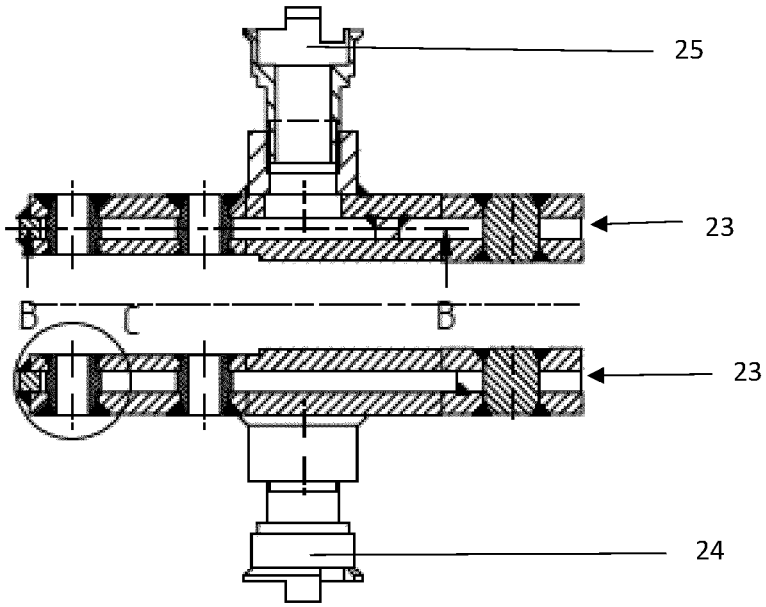

Figure 3b

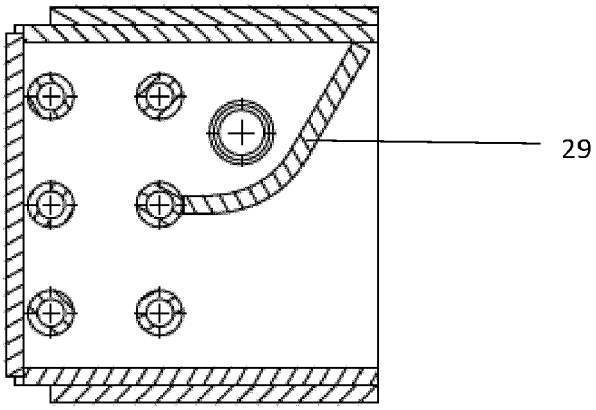

Figure 3c

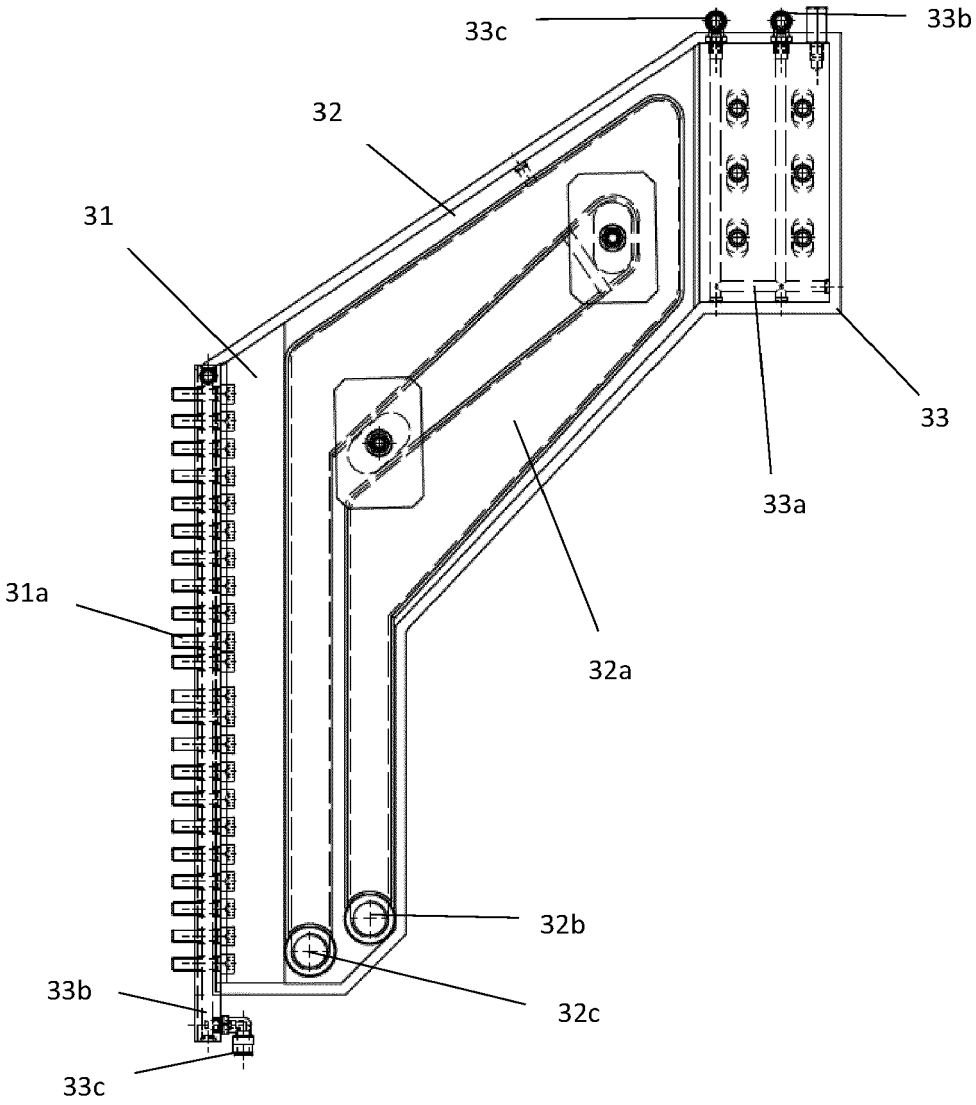

Figure 4a

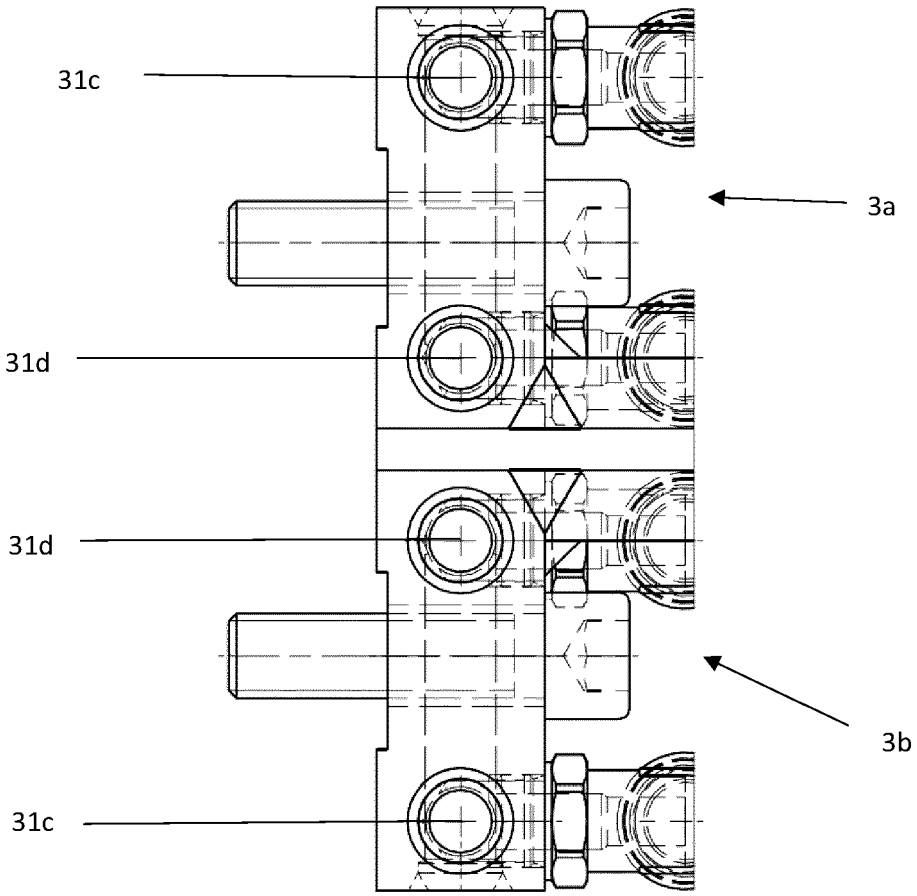

Figure 4b

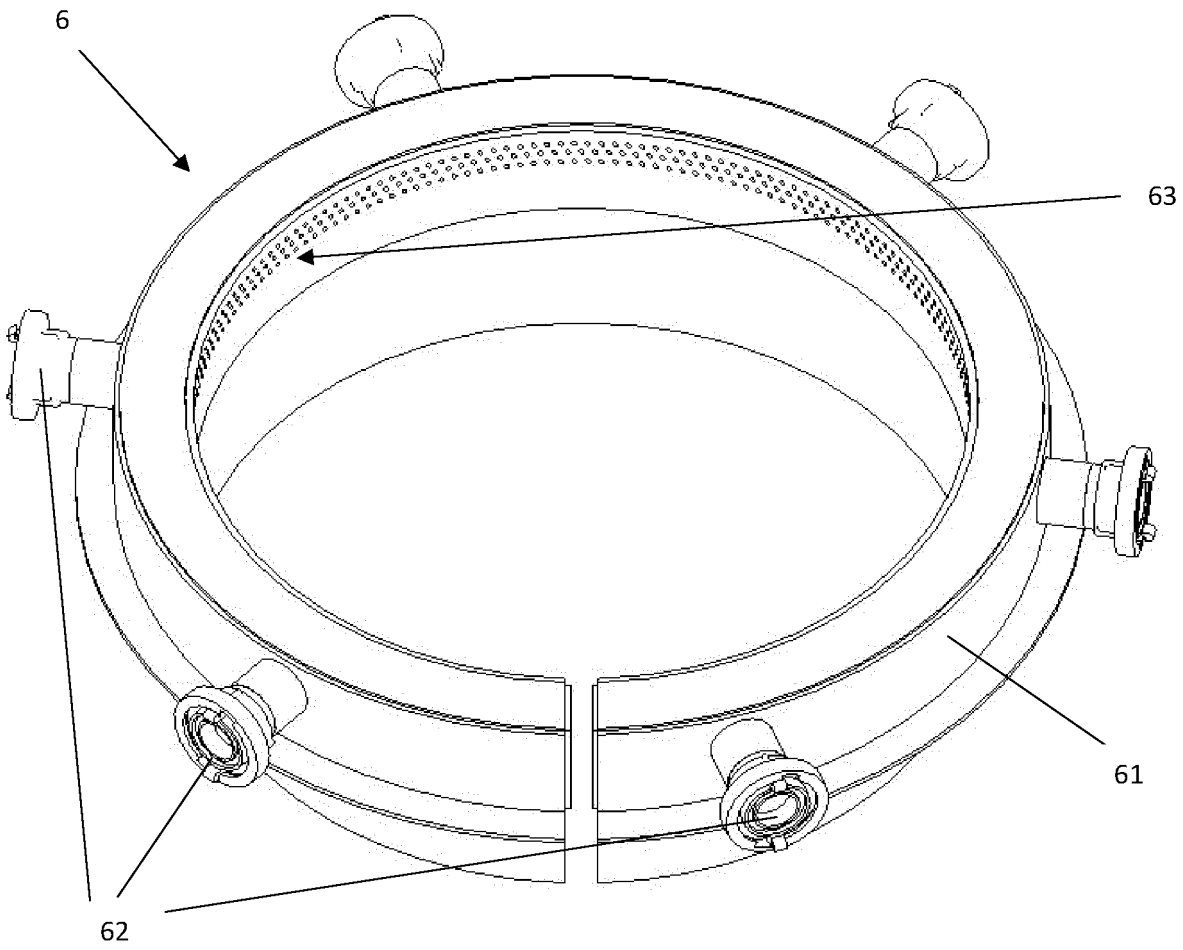

Figure 5

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EUROPEAN SEARCH REPORT

Application Number
EP 23 20 3357

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	27 February 2024	Vermeulen, Yves

CATEGORY OF CITED DOCUMENTS

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REFERENCES CITED IN THE DESCRIPTION

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